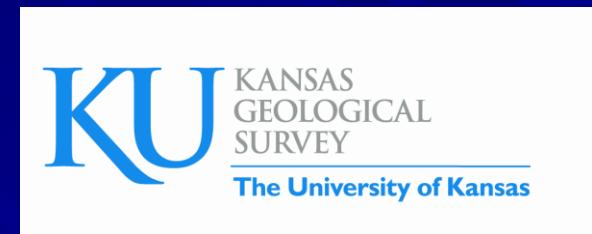


# *Modeling CO<sub>2</sub> Sequestration in a Saline Aquifer and Depleted Oil Reservoir to Evaluate Regional CO<sub>2</sub> Sequestration Potential of Ozark Plateau Aquifer System, South-Central Kansas*



W. Lynn Watney and Saibal Bhattacharya

Kansas Geological Survey  
Lawrence, KS 66047

*Regional Carbon Sequestration Partnerships  
Annual Review Meeting  
October 5-7, 2010  
Pittsburgh, PA*

# Outline of Presentation

- **Project Overview and Objectives**
- **Tasks Completed and In Progress – Initial Results**
  - Regional Study - 17+ county study area, southern Kansas
  - Wellington Field Study – Sumner County, Kansas
  - Initial Simulation Studies
- **Review of Gantt Chart**
  - Tasks and Subtasks scheduled for completion in 2010
  - 2010 Tasks Scheduled to be Completed in 2011
- **Budget**
  - Planned vs. Actual

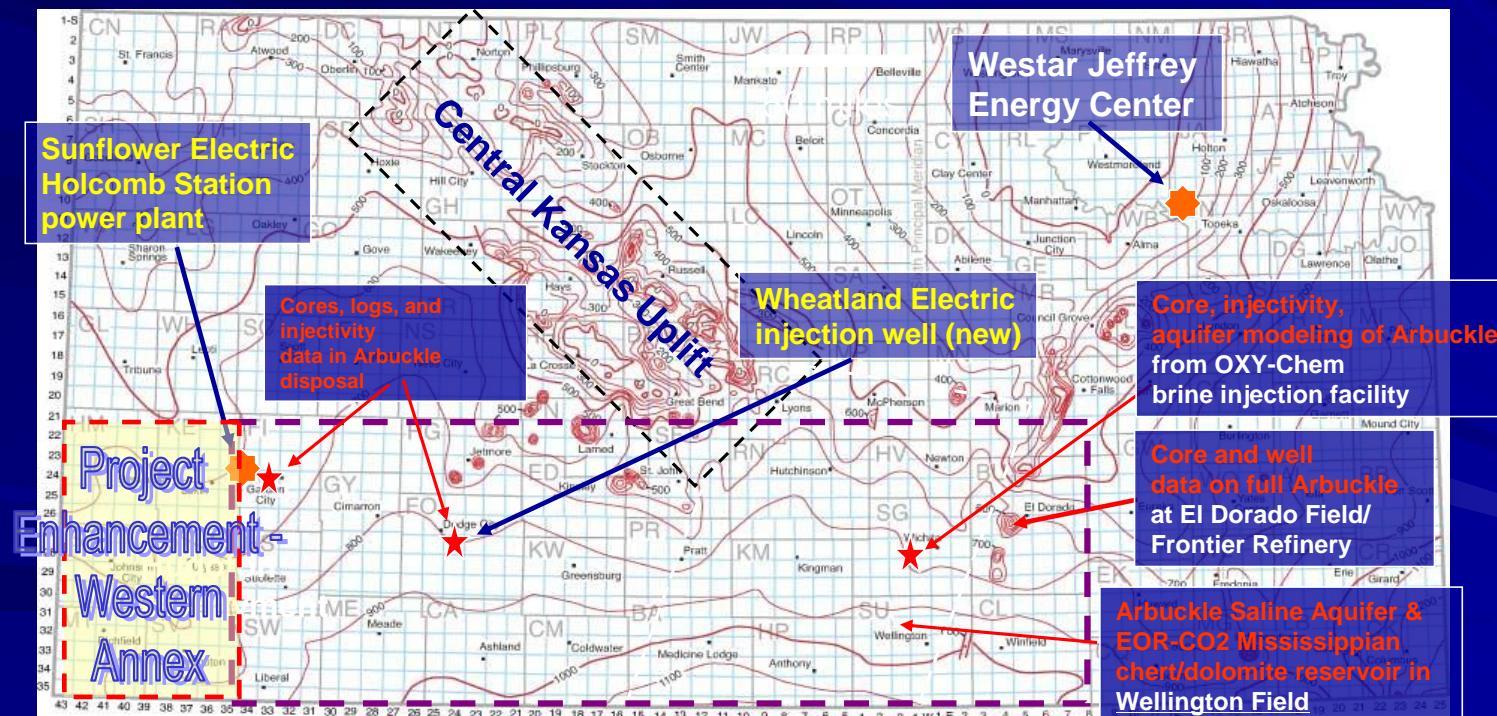
# Overview

Evaluate CO<sub>2</sub> Sequestration Potential in KS

- Deep Saline Arbuckle Aquifer in south-central KS
- Select depleted mature oil fields

Start Date - Dec 2009

No CO<sub>2</sub> will be injected in this 3-year project.



Contours = thickness of Arbuckle Group (100 ft C.I.)

Regional study → ~20,000 sq. miles

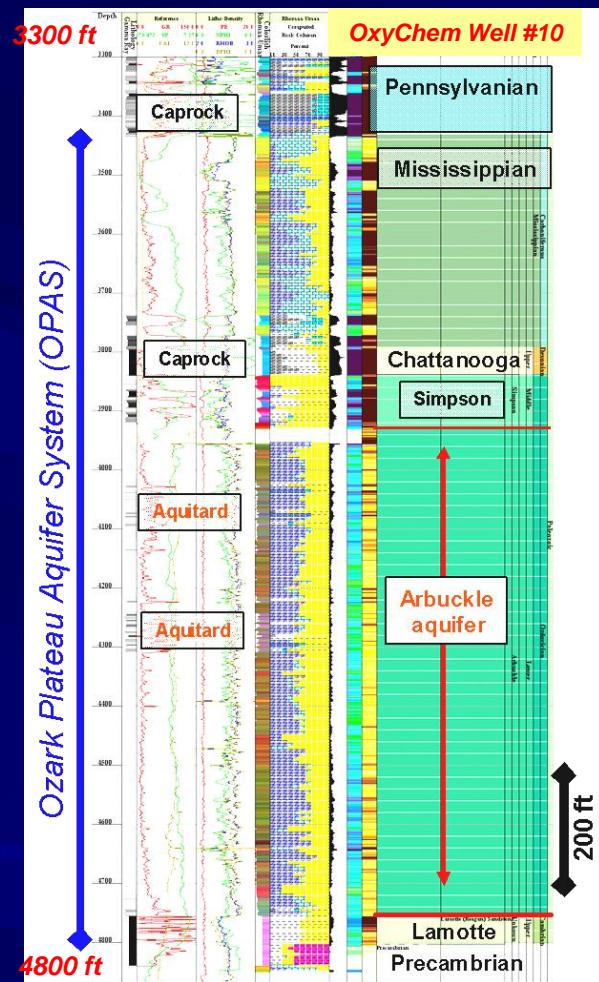
50 miles

# Project Objectives

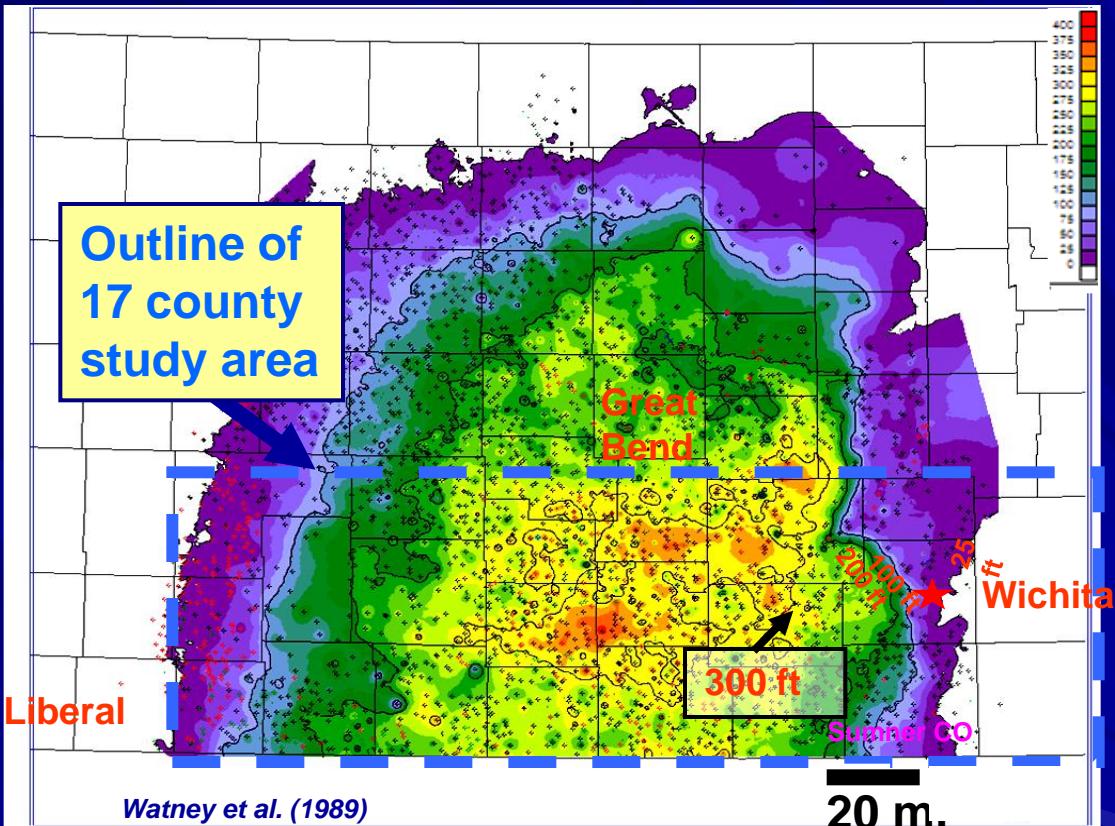
- **Build 3 geomodels**
  - *Wellington field (Sumner County)*
    - *Depleted Mississippian oil field*
    - *Underlying Arbuckle saline aquifer*
  - *Regional Arbuckle saline aquifer - 17+ counties (south-central KS)*
- **Conduct simulation studies to estimate CO<sub>2</sub> sequestration capacity**
- **Arbuckle saline aquifer - 17+ county area**
  - Identify potential sequestration sites
  - Estimate sequestration capacity of Arbuckle saline aquifer in KS
- **Risk analysis related to CO<sub>2</sub> sequestration**
- **Technology transfer**

# Ozark Plateau Aquifer System

Arbuckle Saline Aquifer with Primary, Secondary, and Tertiary Caprocks



Net Halite (salt) Isopach (thickness), CI 100'



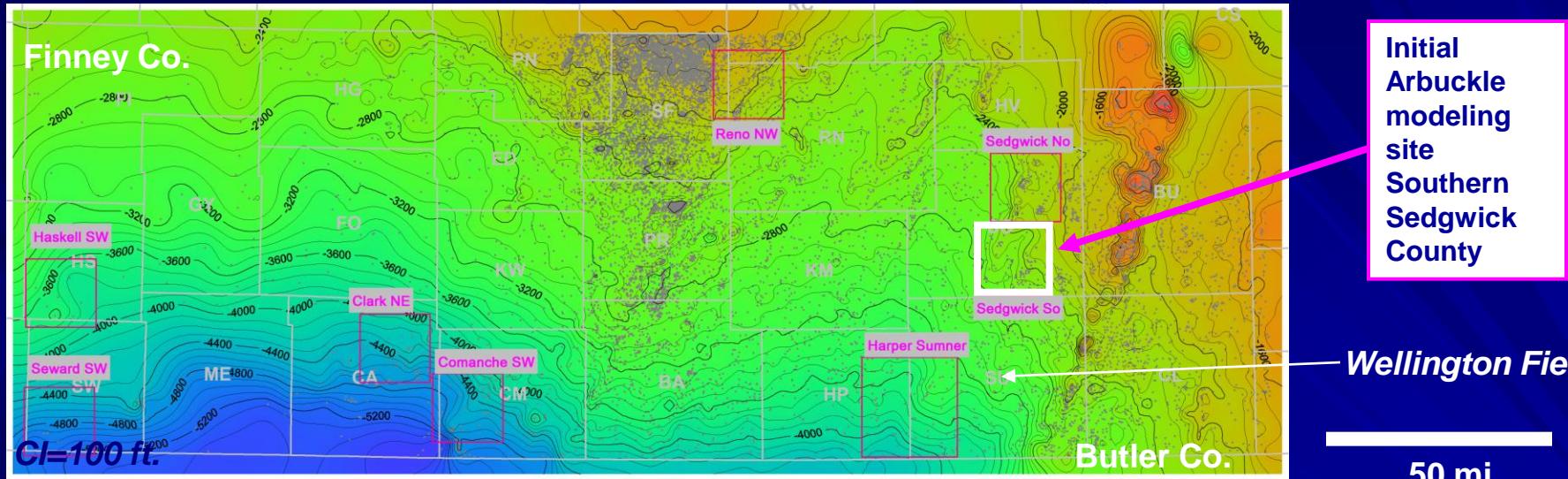
Total Permian evaporite thickness ranges from 400 to 2000' in south-central KS. These evaporites serve as ideal cap rocks being located between shallow freshwater aquifers and hydrocarbon bearing strata and deeper Arbuckle saline aquifer.



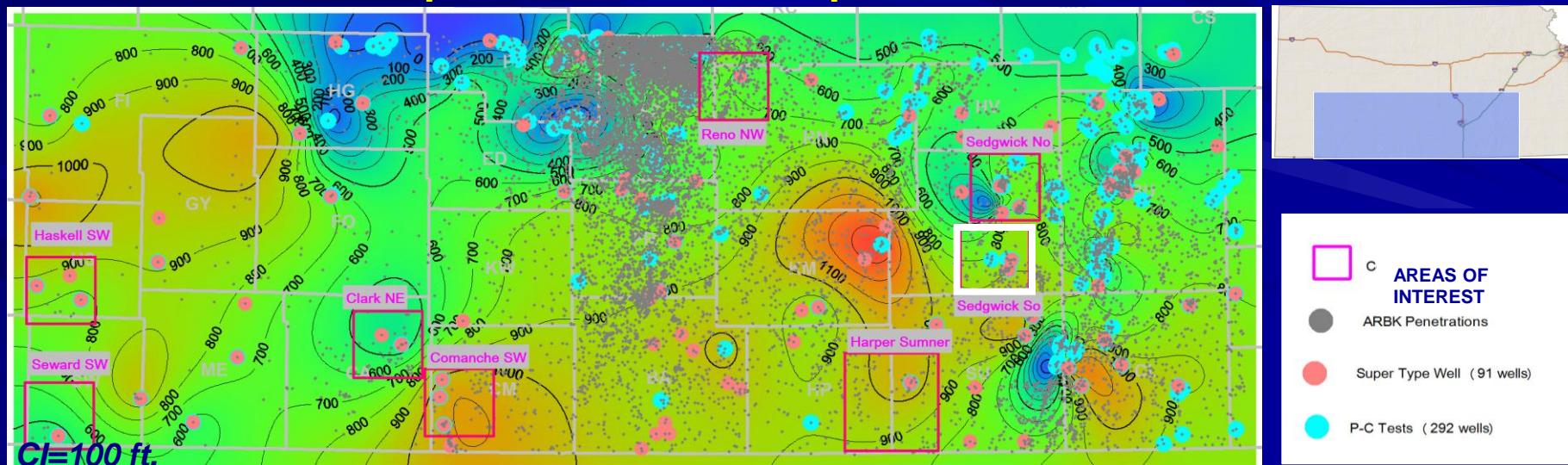
# Regional Study – Tasks Completed and In Progress

## Arbuckle Mapping and Areas of Interest

### Structure top of Arbuckle Group, regional study area



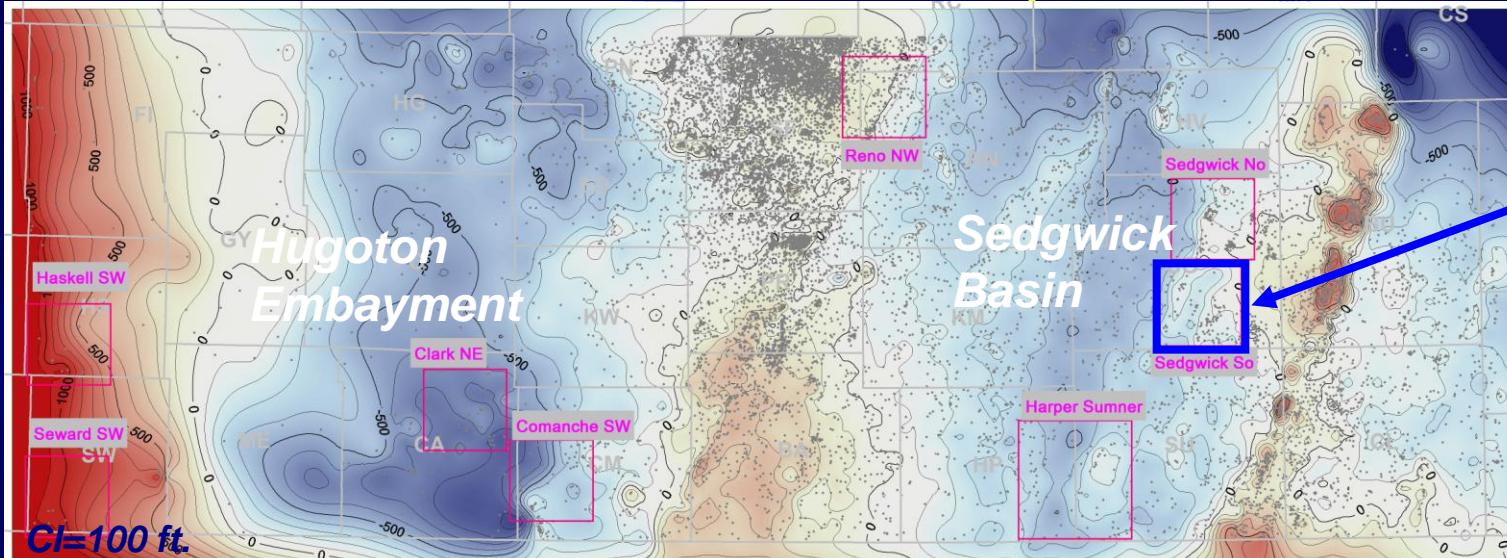
### Isopach Arbuckle Group



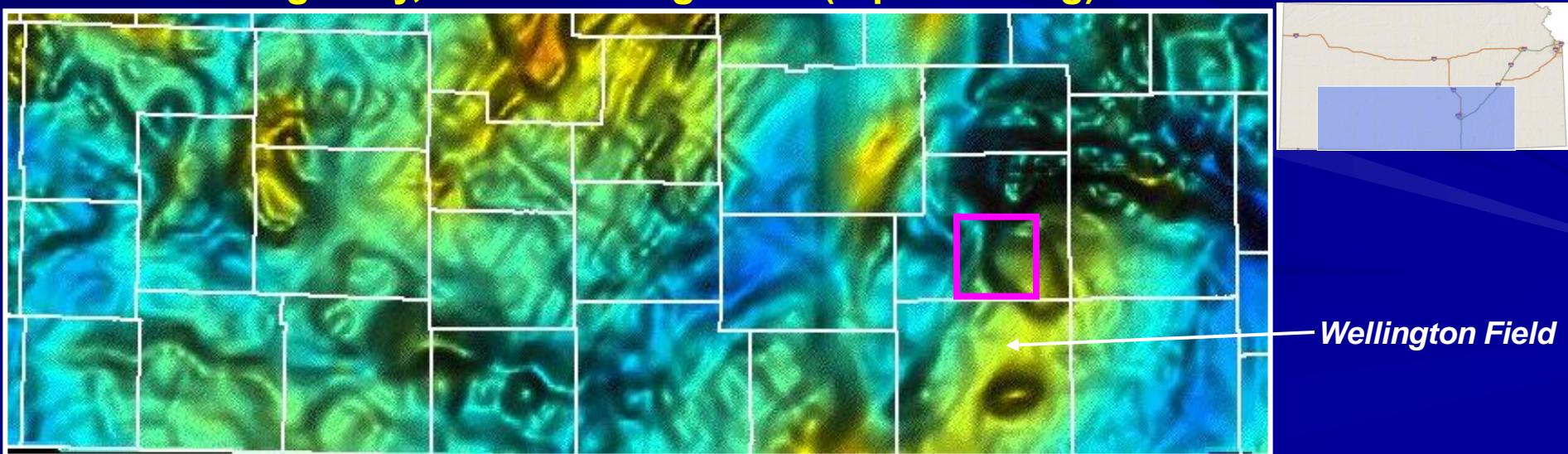
# Regional Study – Tasks Completed and In Progress

## Arbuckle and Potential Fields Mapping

### 3<sup>rd</sup> Order Structural Residual - Top Arbuckle

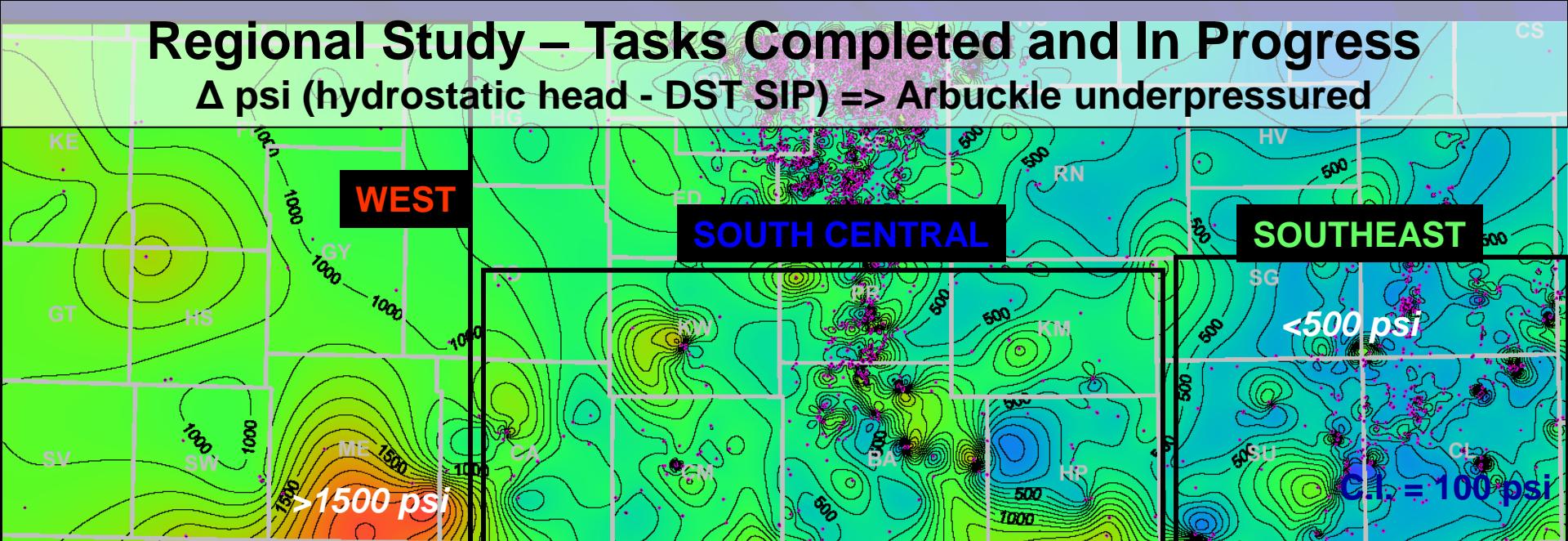


Color = gravity, "relief" = magnetics (reprocessing)

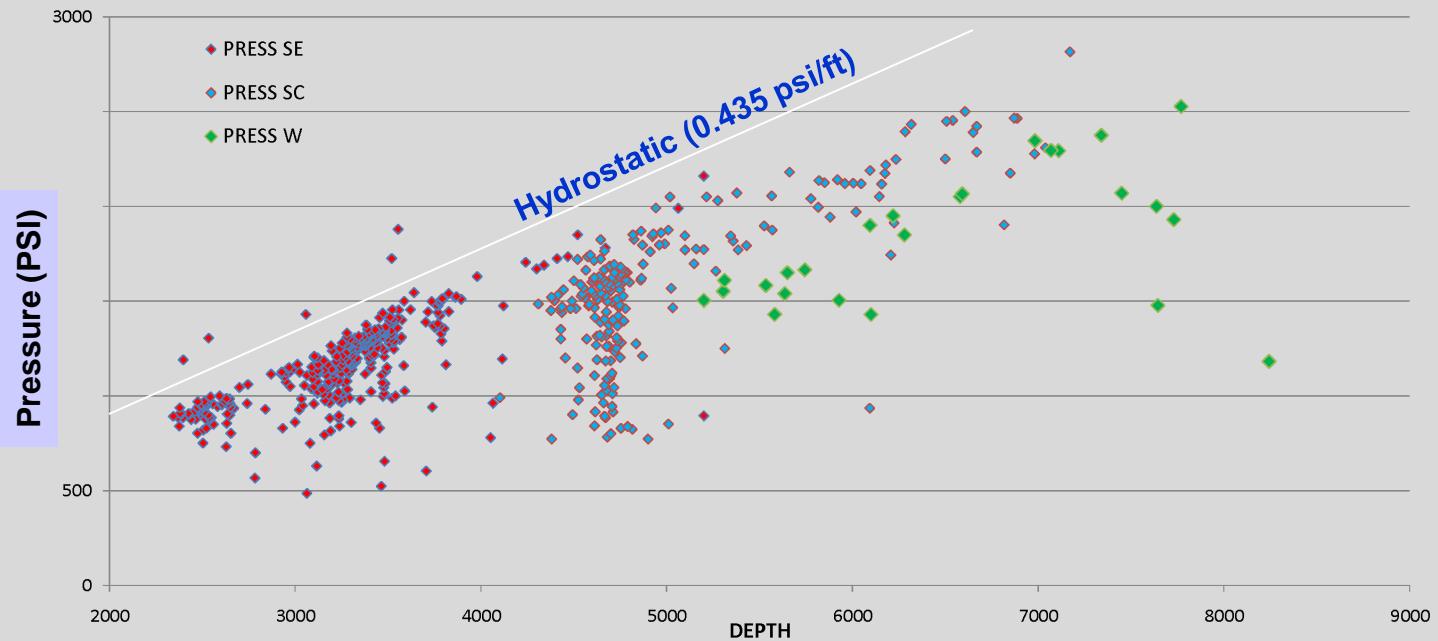


# Regional Study – Tasks Completed and In Progress

$\Delta \text{psi}$  (hydrostatic head - DST SIP) => Arbuckle underpressured



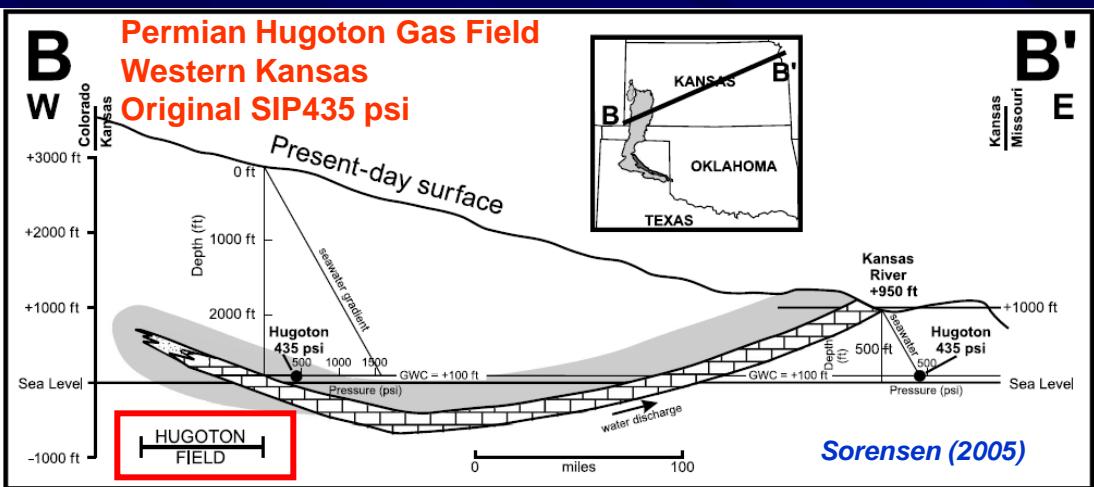
ARBK DST  
DEPTH vs PRESS



**DST shut-in  
pressures  
in Arbuckle  
saline  
aquifer in  
southern  
Kansas**

# Regional Study – Tasks Completed and In Progress

## Arbuckle Saline Aquifer Hydraulically Connected to Outcrop

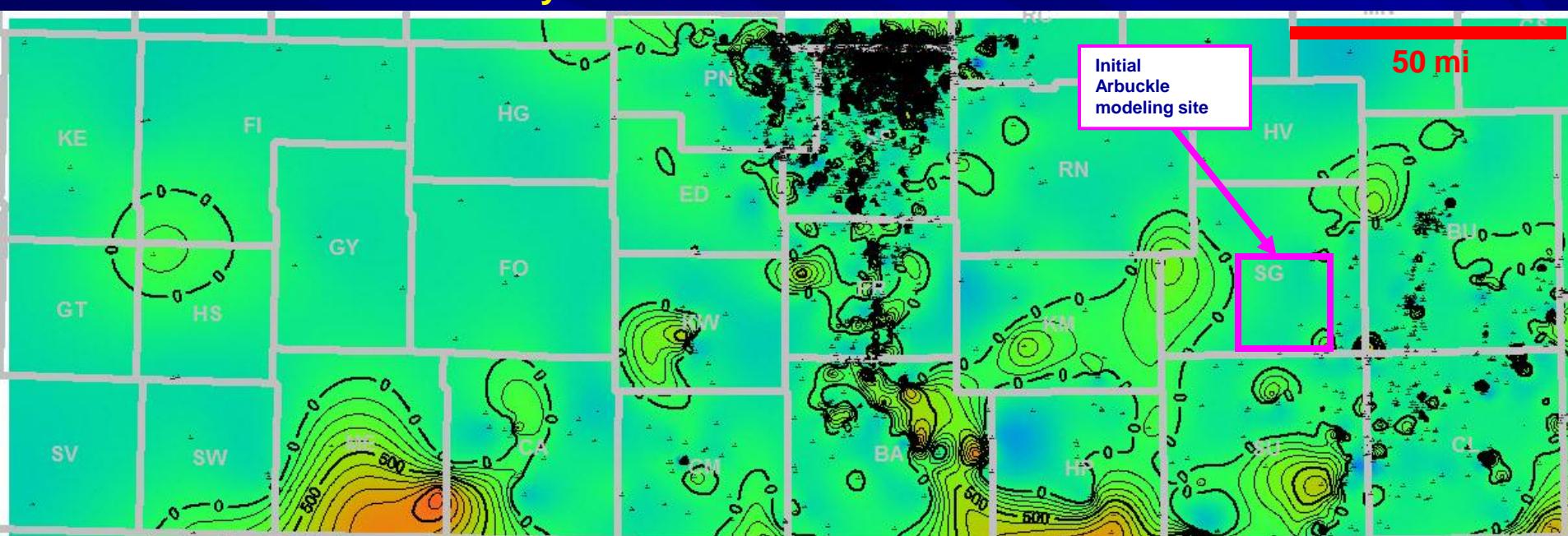


**Arbuckle exposure at base of Missouri River, north-central Missouri – Elevation 450 ft & ~200 mi NE.**

**Assume hydrostatic gradient = 0.435 psi/ft**



**Difference between estimated hydraulic head at base of Arbuckle DST interval and DST SIP**



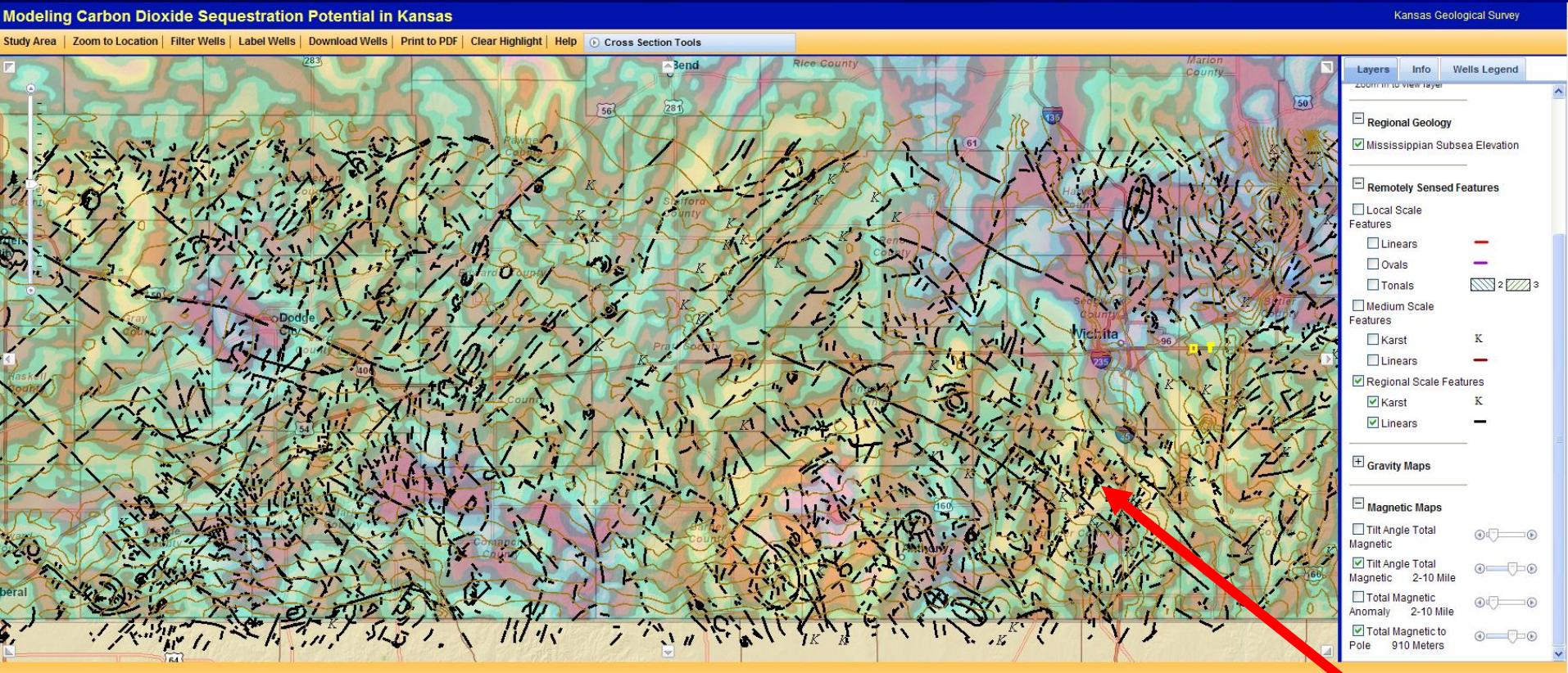
# Arbuckle Saline Aquifer

## Open or Closed System?

- Arbuckle aquifer is hydraulically connected to outcrop in Missouri
  - North-central edge of Ozark Uplift (~200 mi. NE)
- Arbuckle is the preferred disposal zone for produced oil field brine in Kansas
  - No loss of injectivity reported due to increased backpressure after 75+ years of injection
- Majority of Arbuckle hydrocarbon reservoirs produce under strong bottom water drives
- Arbuckle serves as preferred disposal zone for Class 1 hazardous liquid waste
  - Routine measurements at observations wells show minimal to no increase in reservoir pressure after decades of injection

# Regional Study – Tasks Completed and In Progress

## Re-processed Gravity & Magnetics + Remote Sensing Analysis on Interactive Web-based Project Map



### Southern Kansas – project area

Tilt-angle magnetic + Total magnetic field intensity +  
Regional scale lineaments + Structure contour top Mississippian

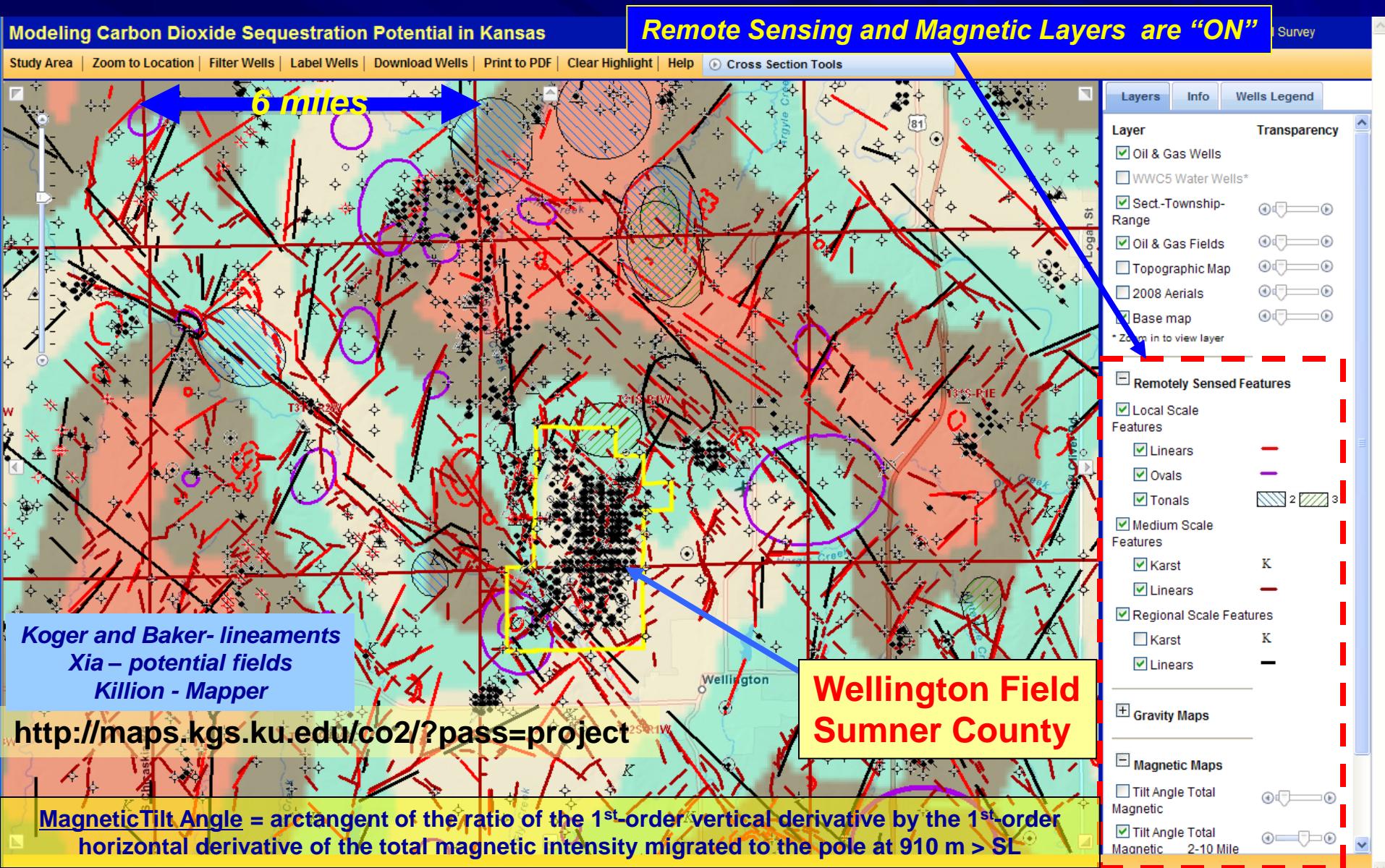
### Wellington Field

50 mi



# Wellington Field Study – Tasks Completed and In Progress

## Landsat Lineaments and Magnetic Tilt Angle near Wellington Field



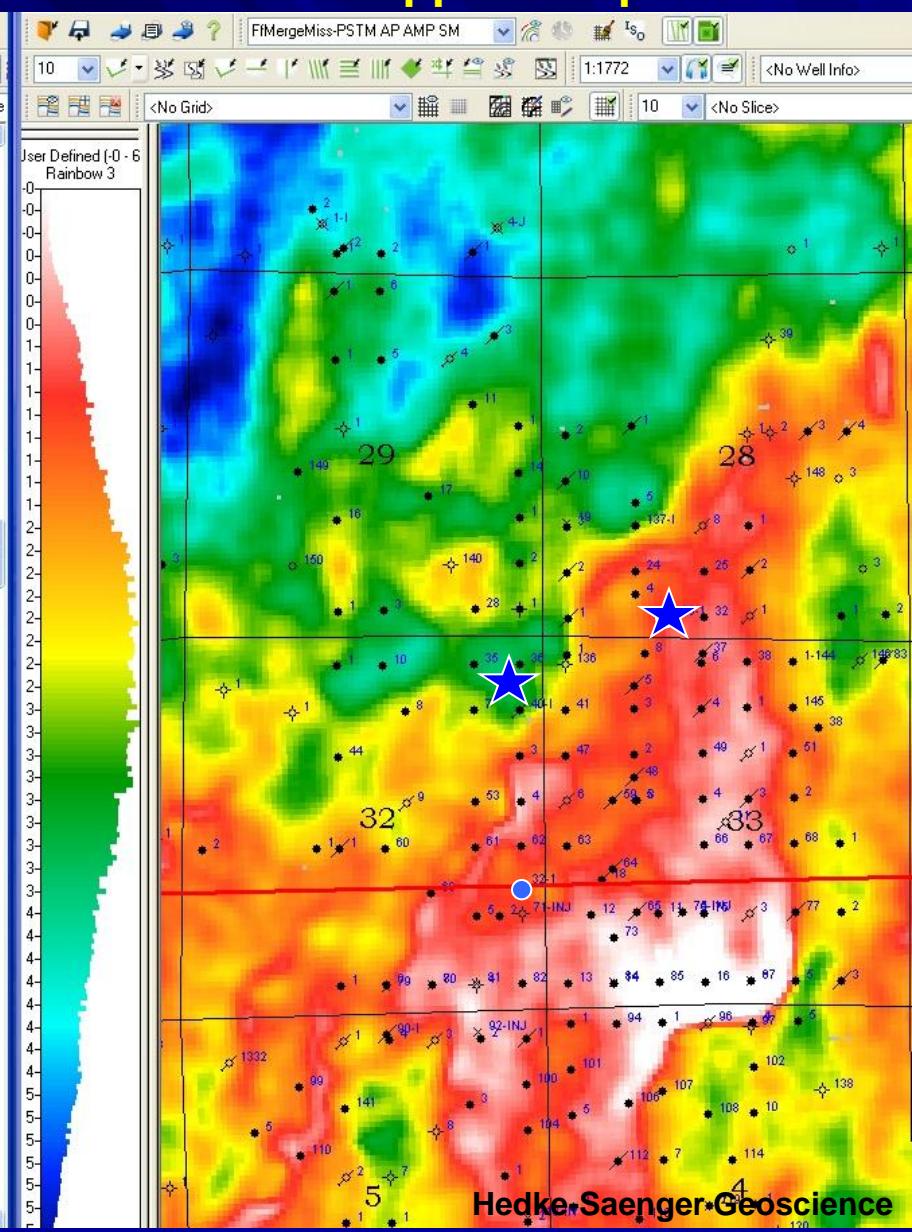
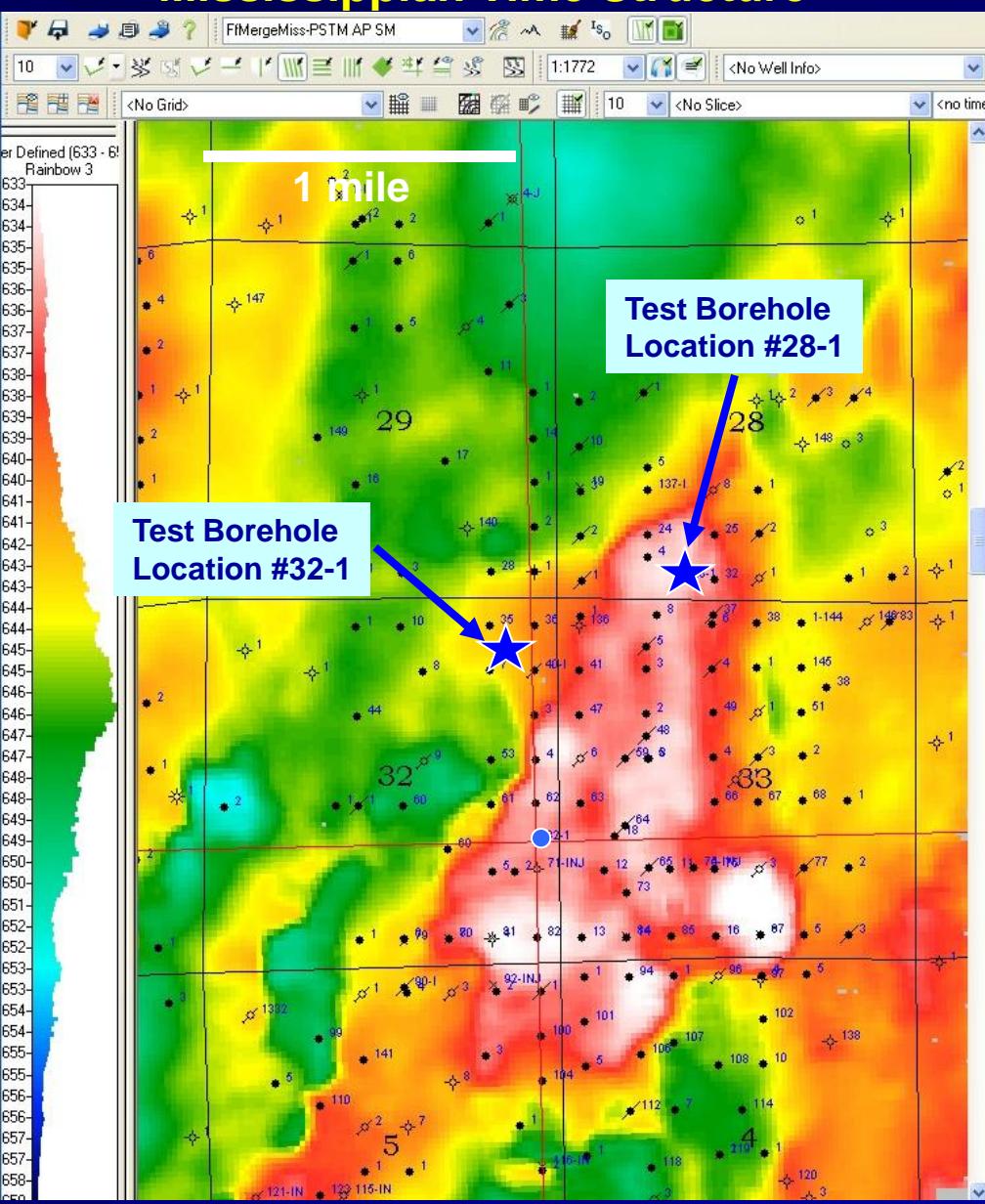
# Wellington Field Study – Tasks Completed and In Progress

3D seismic P-Wave Processing, Initial Interpretations,

& Borehole Site Selection

Mississippian Time Structure

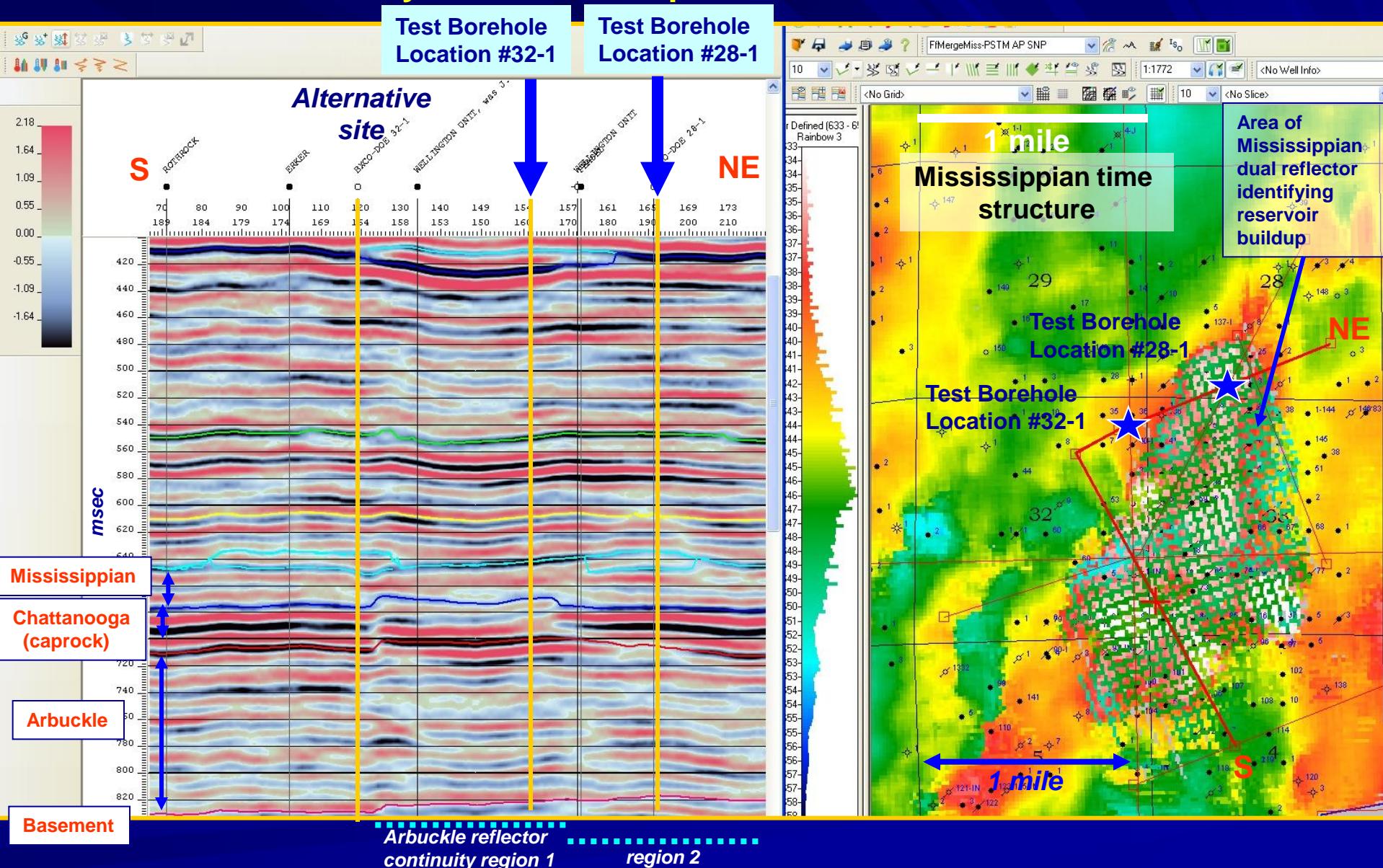
Mississippian Amplitude



# Wellington Field Study – Tasks Completed and In Progress

## 3D Seismic P-Wave Processing, Initial Interpretations, & Borehole Site Selection

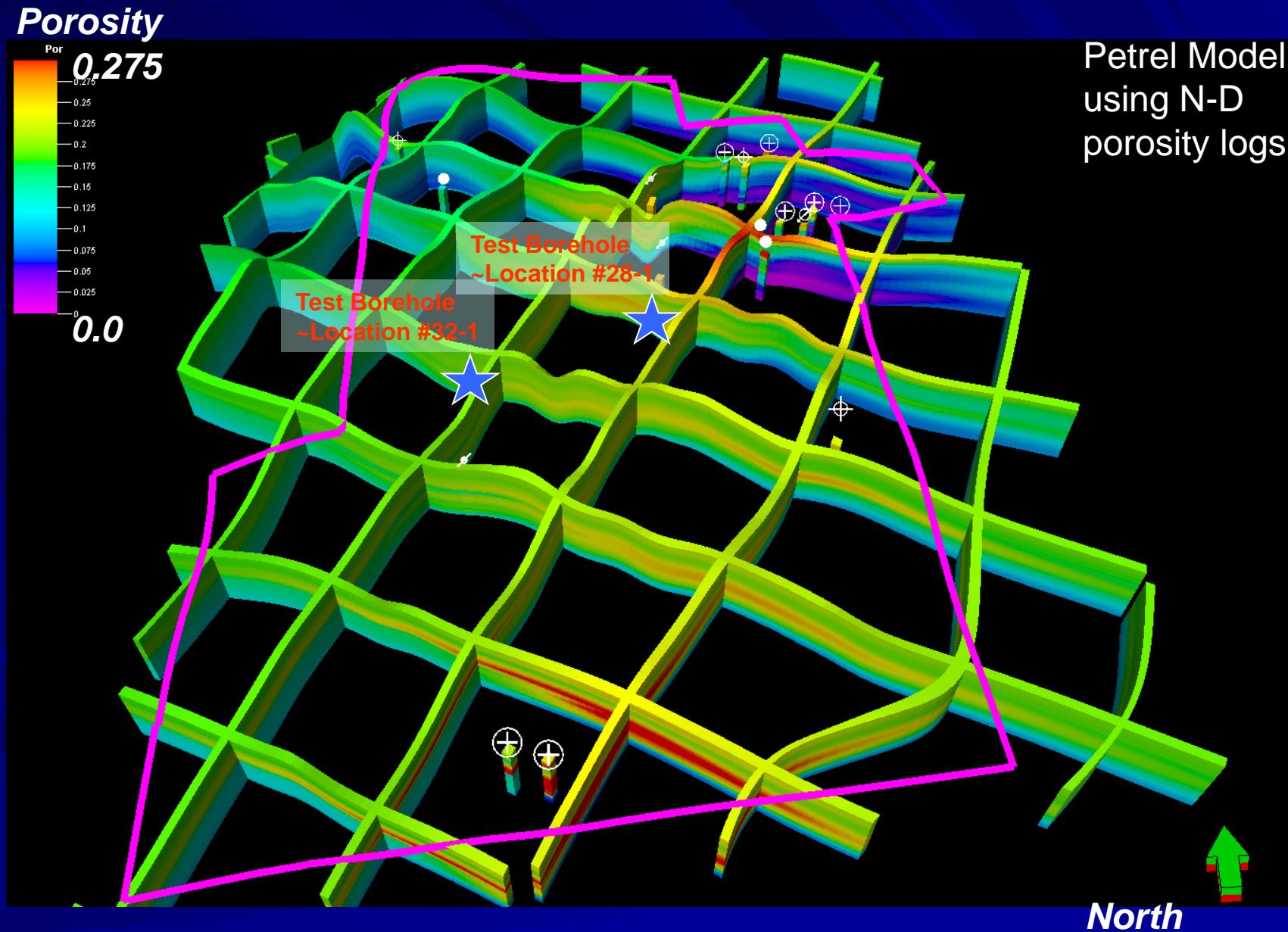
### Arbitrary Profile to Compare Test Borehole Locations



# Wellington Field Study – Tasks Completed and In Progress

## Porosity Fence Diagram

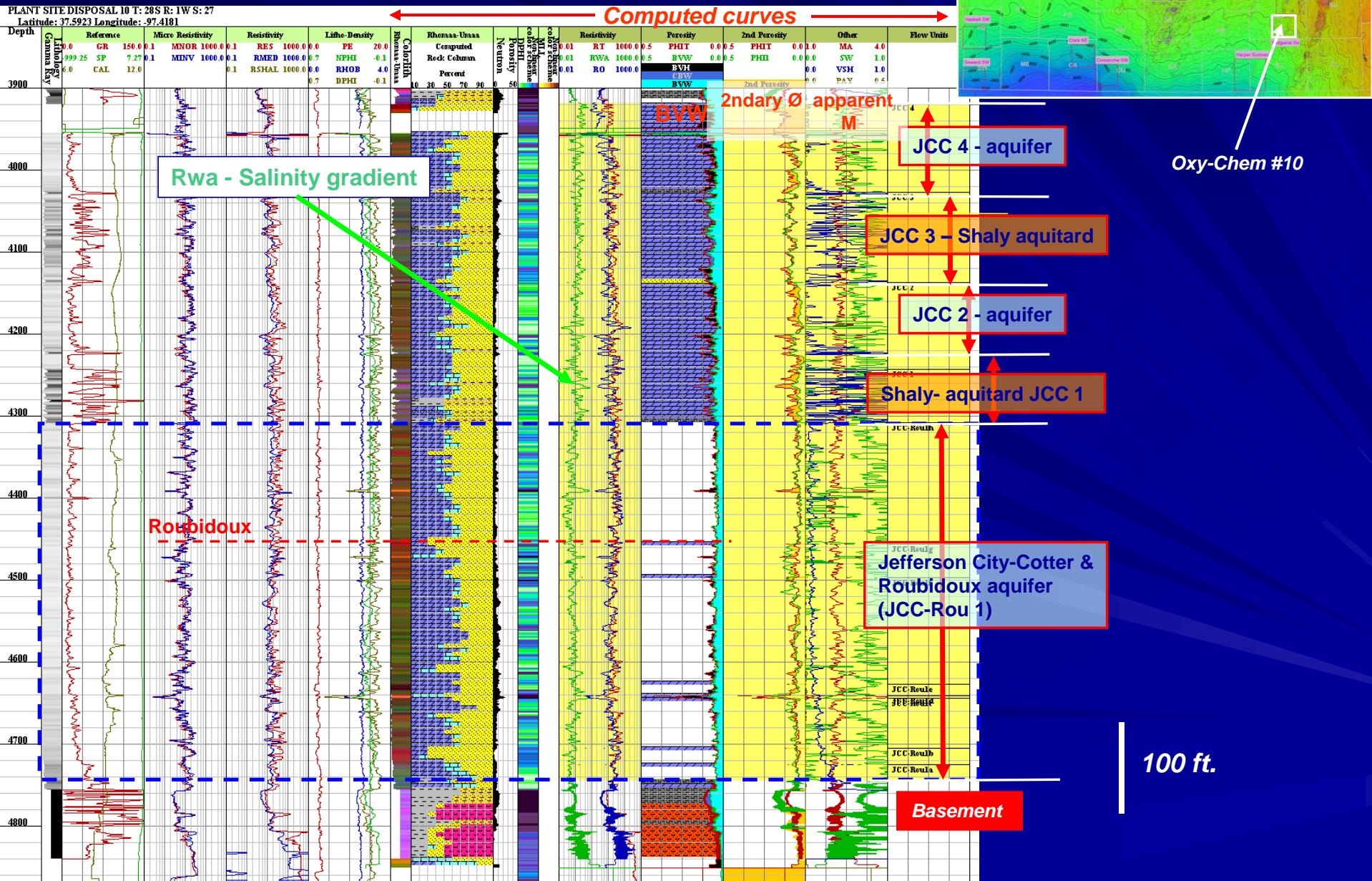
### Mississippian Oil Reservoir



# Initial Simulation Studies – Tasks Completed and In Progress

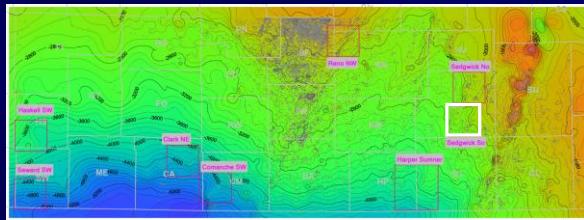
## Arbuckle Flow Unit Characterization using depth-constrained clustering

### Java-tool WELL PROFILE



## **Initial Simulation Studies – Tasks Completed and In Progress**

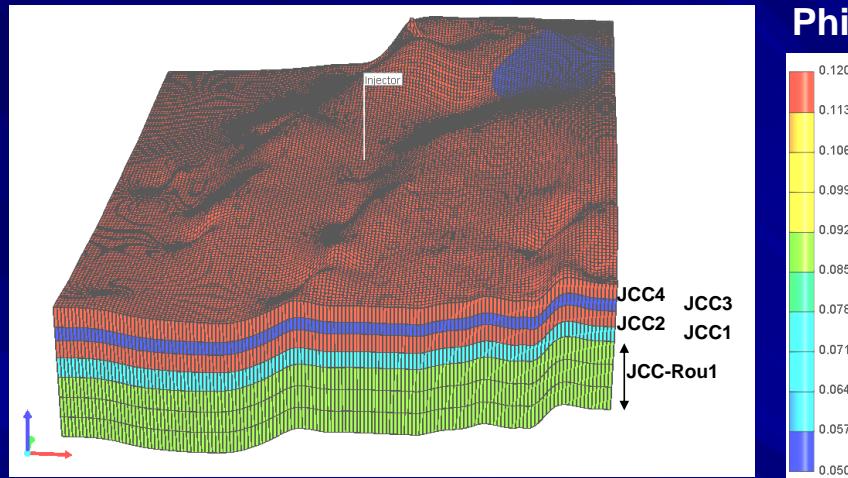
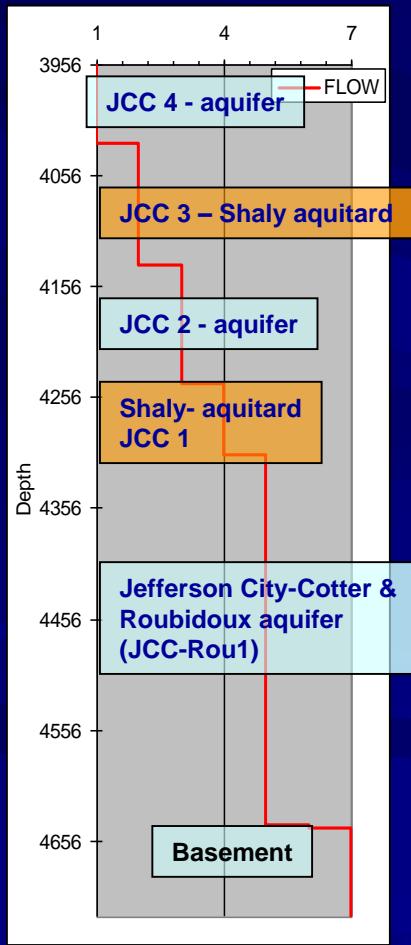
### **9 Township Model – centered around Oxy-Chem #10**



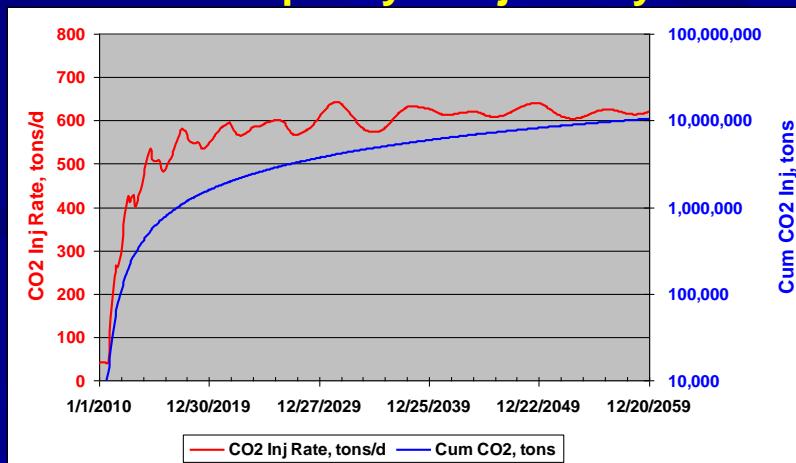
# Grids: 330' by 330'

**Injection pressure < fracture pressure (3000 psi)**

## **Injection from 2010 to 2060. Run till 2200.**



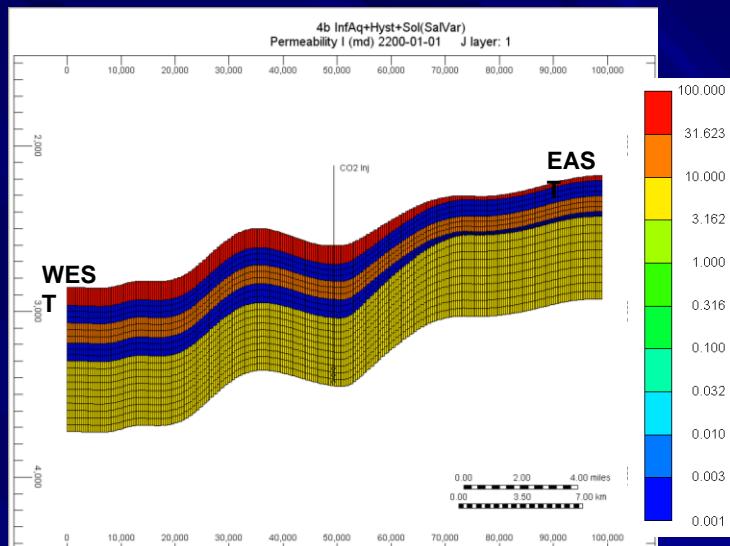
# Capacity & Injectivity



# Initial Simulation Studies – Tasks Completed and In Progress

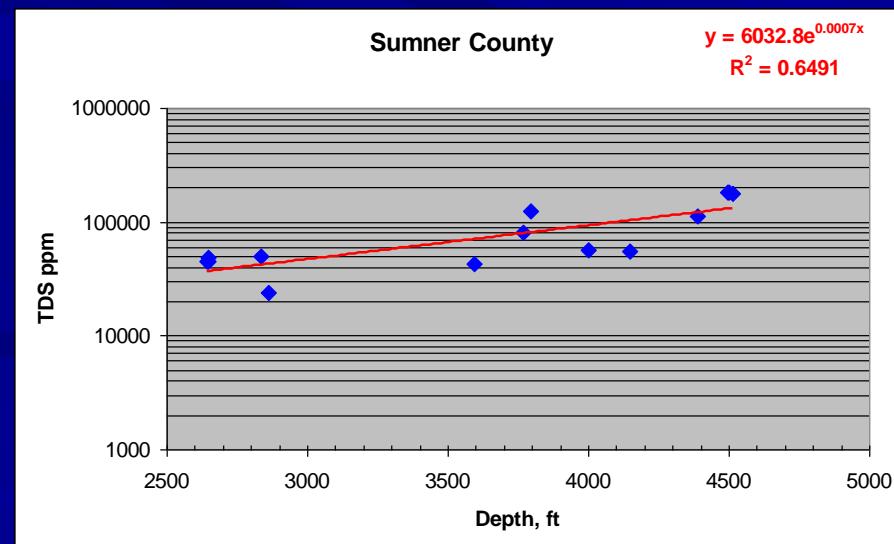
## 2D Model around Oxy-Chem #10 – 20 Layer Model Inputs

**Approximately 300 core analysis archived from Arbuckle reservoirs – Byrnes et al 2003**



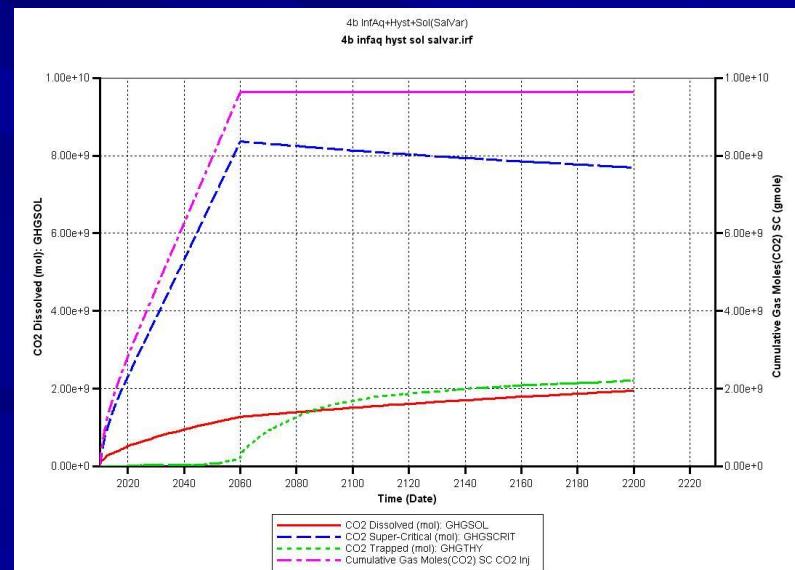
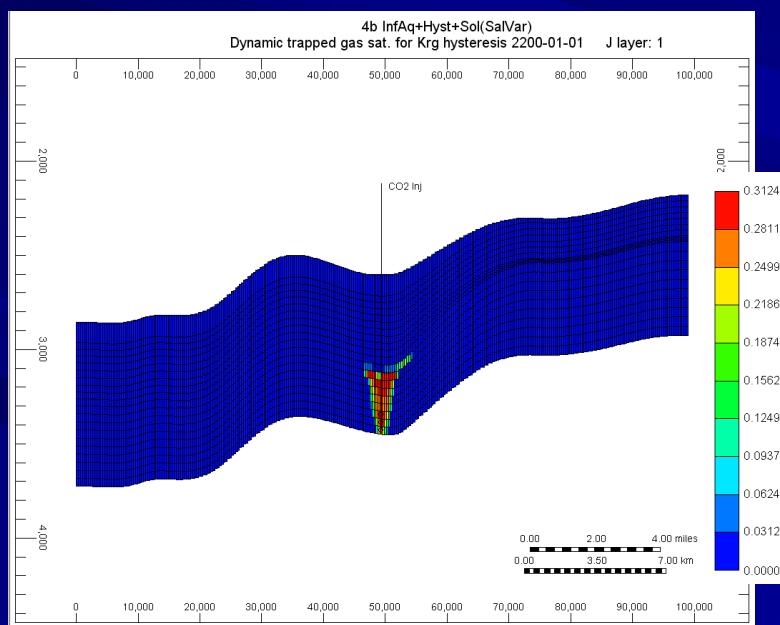
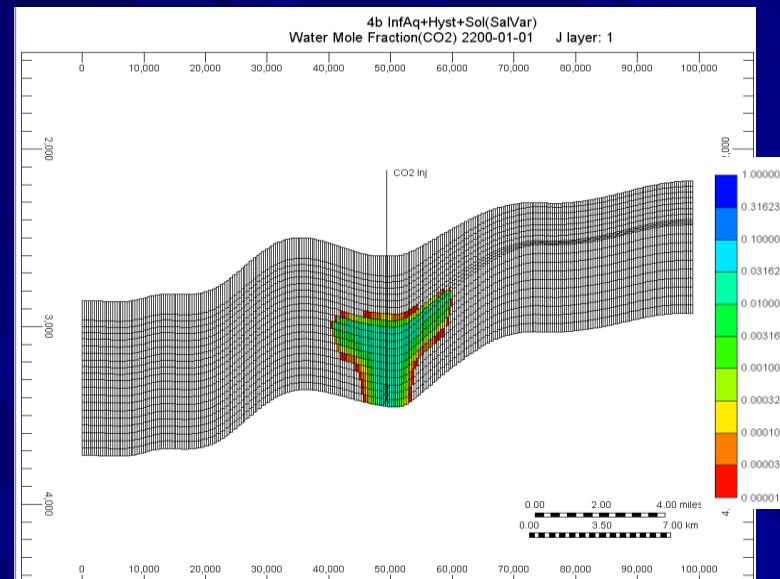
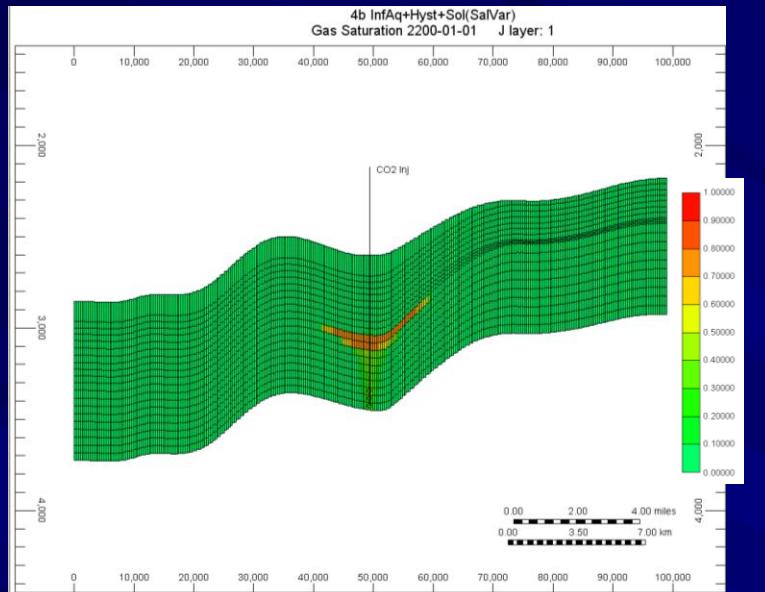
Flow units	Layers	Oxy-Chem #10		Sumner CO			
		Avg Depth	Pr - Hyd Head	Frac Pr	ppm	Phi	K, md
1	1	2658.5	1245	3009	100079	0.12	100
2	2	2732	1277	3065	105363	0.05	0.001
2	3	2765.5	1292	3090	107863	0.05	0.001
2	4	2799	1307	3115	110422	0.05	0.001
3	5	2834.5	1322	3141	113201	0.12	20
3	6	2871	1338	3169	116130	0.12	20
3	7	2907.5	1354	3196	119135	0.12	20
4	8	2944.5	1370	3224	122261	0.06	0.001
4	9	2981.5	1386	3252	125469	0.06	0.001
4	10	3019	1402	3280	128806	0.06	0.001
5	11	3058.5	1419	3309	132418	0.09	10
5	12	3099.5	1437	3340	136273	0.09	10
5	13	3140.5	1455	3371	140241	0.09	10
5	14	3181.5	1473	3402	144324	0.09	10
5	15	3222.5	1491	3432	148526	0.09	10
5	16	3263.5	1509	3463	152851	0.09	10
5	17	3304	1526	3494	157246	0.09	10
5	18	3344.5	1544	3524	161768	0.09	10
5	19	3385.5	1562	3555	166478	0.09	10
5	20	3426.5	1580	3585	171325	0.09	10

### Salinity vs. Depth



# Initial Simulation Studies – Tasks Completed and In Progress

## 2D Model around Oxy-Chem #10 – 20 Layer Model Results

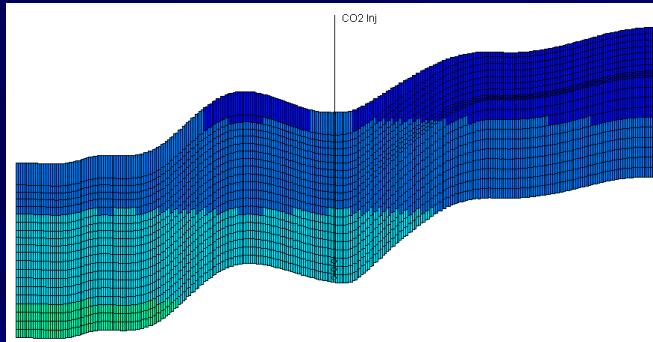


# Initial Simulation Studies – Tasks Completed and In Progress

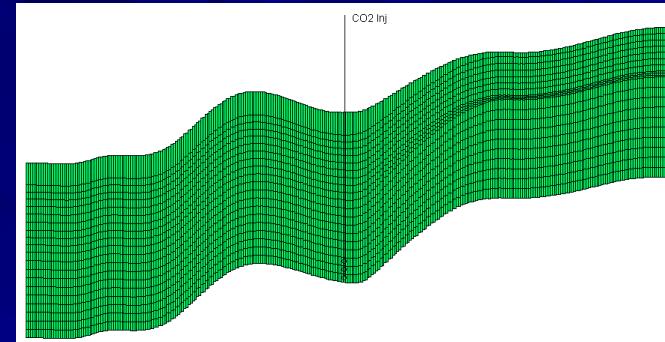
## 2D Model around Oxy-Chem #10 – 20 Layer Model Results

### Pressure Leakage (brine) through Cap Rock

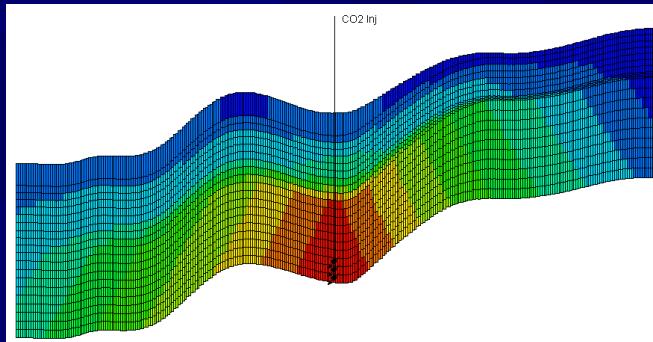
Jan 1, 2010 - Pressure, psi



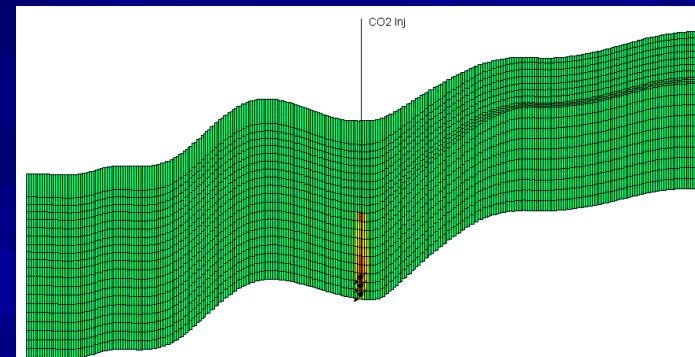
Jan 1, 2010 - Sg



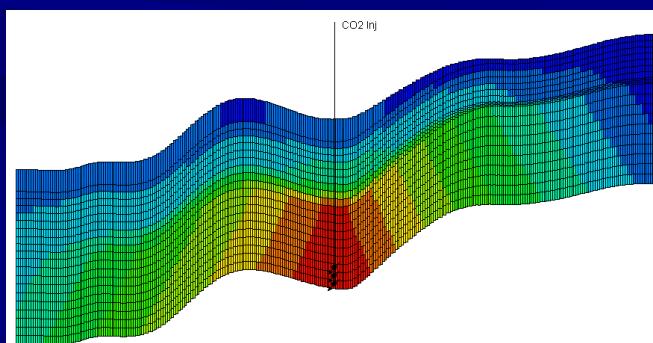
Jan 1, 2035 - Pressure, psi



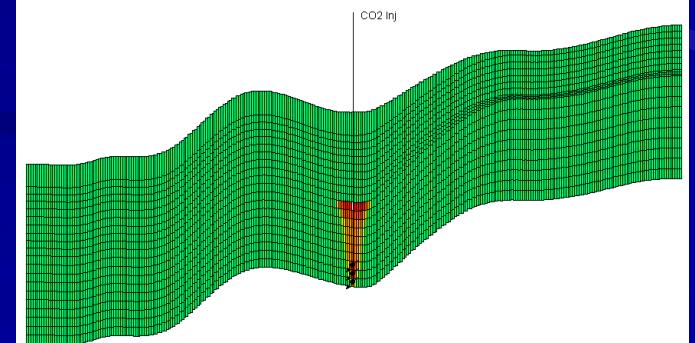
Jan 1, 2035 - Sg



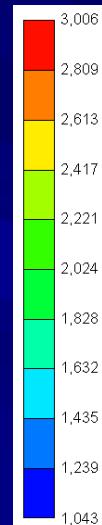
Jan 1, 2060 - Pressure, psi



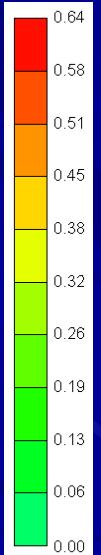
Jan 1, 2060 - Sg



Psi

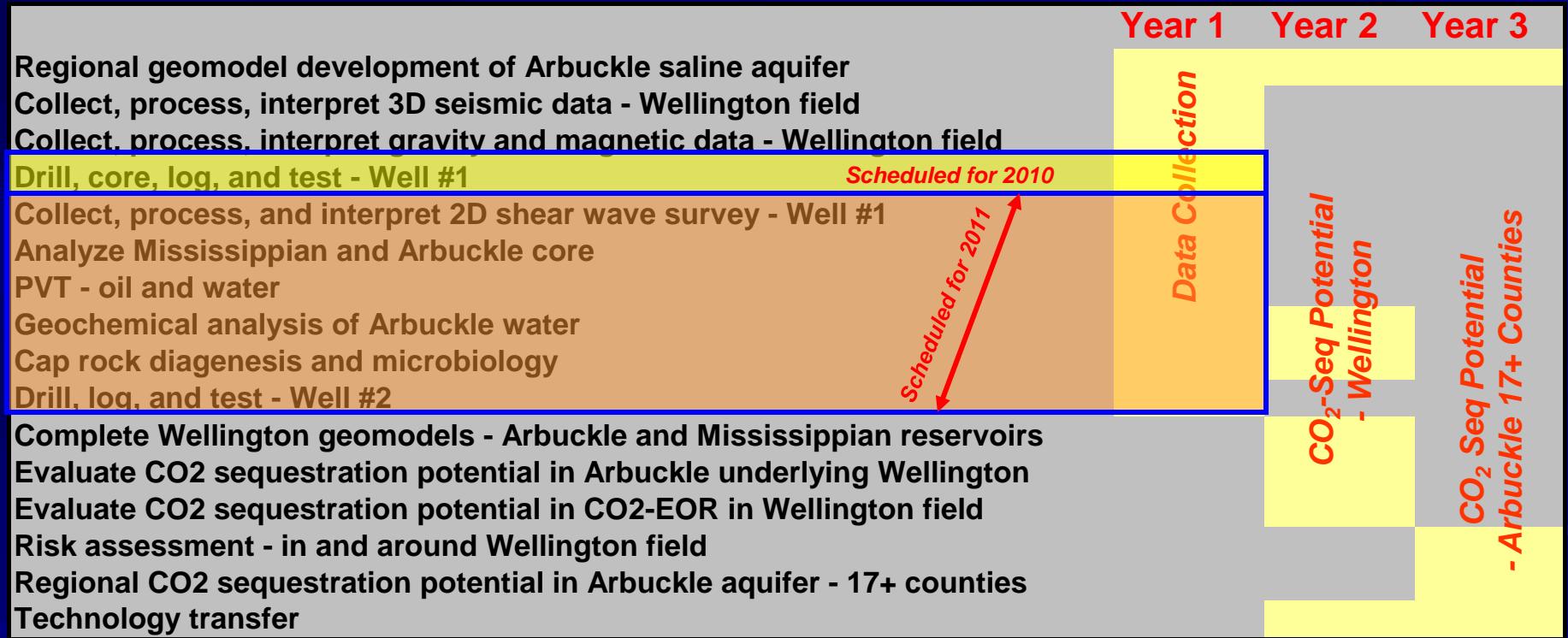


Sg



# Gantt Chart Review

## 2010 Tasks - Completed, In Progress, & Scheduled for 2011



## 2010 Budget Planned vs. Actual Expenditure

	4th Qtr 2009	1st Qtr 2010	2nd Qtr 2010	3rd Qtr 2010	4th Qtr 2010
	Dec-09	Mar-10	Jun-10	Sep-10	Dec-10
Actual DOE Cost	\$4,019.93	\$84,603.97	\$494,428.37		
Planned DOE Cost	\$1,273.10	\$330,271.41	\$330,271.41	\$1,302,953.72	\$2,065,719.27

## Revised Schedule

- Sites selected for test bore holes #1 & 2
- Industry partner (BEREXCO) completing land/lease legal work
- Rig to move to location for drilling test bore hole #1 – 3<sup>rd</sup> week of Nov 2010
- Rig reserved for 3 months
  - Will drill test bore hole #2 after completion of #1 – back to back
- 2D shear wave survey shot after drilling test bore hole #1
  - Complement multi-component 3D seismic survey (already surveyed)
- Core Analysis – mid-2011
- Geochemistry – mid-2011
- Revise Geomodel & Simulation – later half of 2011



**Thank You**



U.S. DEPARTMENT OF  
**ENERGY**

DEPARTMENT OF  
**GEOLOGY**

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Department of Geology



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